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RESEARCH PAPER

Tree Seed Procurement–Diffusion Pathways in Wonogiri and Ponorogo, Java

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Abstract Forty-two percent of the land area in the neighbouring districts (kapubatens) of Wonogiri, Central Java and Ponorogo in East Java is covered with secondary forests of naturalized exotic tree species that are common components of governmental land rehabilitation programs. The seed suppliers operating in the Wonogiri–Ponorogo area represent only 9% of the suppliers in Indonesia yet they account for 80–90% of the national tree seed supply capacity. Wonogiri–Ponorogo suppliers procure and sell 1,510 tons of seed annually. About 24% of this (362 tons) is exchanged between suppliers, 1,148 tons are sold to customers across Indonesia, and less than 1 ton is exported. About 72% of the seed sold (826 tons) is collected in the Wonogiri–Ponorogo area, the remainder originating in Sumatra, Madura and Nusa Tenggara. In Wonogiri–Ponorogo, tree seeds are collected by farmers on contract with seed assemblers or seed companies. Assemblers link farmer collectors with seed companies and middlemen, who sell seed to customers. Government agencies purchase 75% of the seed. Cover crop species, *Gmelina arborea*, *Tectona grandis* and *Leucaena leucocephala* account for the 85% of the total seed sold. The sheer volume of seed collected in Wonogiri–Ponorogo assures that it comes from a large number of unrelated trees over widely dispersed locations. However, research results indicate individual farmers collect seed from a limited number of adjacent trees. Experience indicates simple seed collection guidelines help farmers improve their seed collection practices and the genetic quality of seed collected. A commitment to seed quality by all agents involved in the seed trade and customers is required to make such guidelines functional and acceptable. Seed procurement and diffusion generate significant income for all seed agents. As the dominant agents who facilitate

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most of the activities and inputs required to move seed through the pathway from forests to customers, seed companies receive the most financial benefits. Farmer seed collectors are the most numerous agents in the seed pathway, with an estimated 22,500 farmers involved in seed collection activities annually. Farmer families living near seed companies earn additional income by processing seed.

Keywords Reforestation · Land rehabilitation · Tree seed collection · Tree seed sources · Tree seed quality · Tree seed markets · Tree seed revenue

Introduction

Government agencies, industrial forestry companies, and numerous non-government organizations (NGOs) and farmer groups throughout Indonesia are involved with reforestation or other tree-planting activities. All of these groups can make important contributions to rehabilitating the estimated 15.1 M ha of degraded land in Indonesia (MOF 2001). The Government of Indonesia (GOI) set an ambitious target of reforesting 3 M ha during the 2003–2007 period (MOF 2003).[1] The success of tree-planting activities depends on many factors. The most important physical factors are tree seed quality and quantity. Seed quality determines the upper limits of yield and the productivity of labour, fertilizers and other inputs (Cromwell 1990; Cromwell et al. 1992). Even without increasing other inputs, high quality seed will enhance growth and productivity, particularly on degraded sites (Simons et al. 1994). Adequate quantities of seed assure planting targets can be achieved. However, adequate quantities of high quality tree seed often are not available. NGOs and farmer groups active with tree planting activities in Indonesia lack access to tree seed of sufficient quantity and quality (Roshetko 2001). Many projects and government offices face similar shortages. In the past, a paucity of information regarding tree seed suppliers aggravated the seed shortage problem. The publication of a directory of Indonesian tree seed suppliers (Roshetko et al. 2003) has helped fill this information gap.

Wonogiri, Central Java and Ponorogo, East Java—separated by only 75 km—are widely acknowledged as the main source of tree seed in Indonesia. Large areas of these districts are covered with secondary forests, composed of the naturalized exotic species that are primary components of government reforestation and private tree-planting programs. Wonogiri–Ponorogo is centrally located on Java, which is the population, financial and government center of Indonesia. In the 1980s a locally operated tree seed procurement and diffusion system or *pathway* evolved in Wonogiri–Ponorogo to serve the national land rehabilitation effort. Understanding the operation, linkages and capacity of this seed pathway is a vital first step in evaluating the quality and quantity of tree seed available to seed users in Indonesia. To develop such an understanding, a study was conducted in Wonogiri–Ponorogo to: (i) document the local tree seed collection–diffusion pathway; (ii) assess the quality, quantities and flows of seed collected and distributed; (iii) identify principal

[1] An evaluation of the reforestation program is scheduled.

species for which germplasm is collected and sold; and (iv) estimate the economic impact of seed collection activities on the various tree seed agents.

Research Method

Geographic Description of Survey Area

Wonogiri and Ponorogo are neighbouring districts or *kabupaten* and share similar ecological characteristics. Elevations are generally between 100 and 600 m, with Ponorogo including a mountain range that rises to 2,500 m. Mean annual temperatures are 24–32°C in the lowlands and 18–26°C at higher elevations (BPS Ponorogo 2000; BPS Wonogiri 2000). Annual rainfall is about 1900 mm with high intensities between October and June. July through September is the dry season with rainfall generally below 500 mm/month. Typical of east-to-west gradients in Java, Ponorogo is hotter and drier than Wonogiri. Upland soils are lithosols of limestone origin, well drained and depleted of nutrients. Lowland soils, of volcanic origins, support productive irrigated rice systems that yield three crops per year. Upland cropping systems (corn, upland rice or cassava) are less productive and profitable due to inherently infertile soils and reliance on rainfall, which is low and strongly seasonal. As agricultural yields declined and timber markets developed, farmers and government agencies (the forest department, state forest company, and watershed management department) converted abandoned upland fields to tree farms. Approximately 42% of the two districts is covered with secondary forests—homegardens, community forests and state plantations—composed of naturalized exotic timber species (*Gmelina arborea*, *Paraserianthes falcataria*, *Swietenia macrophylla* and *Tectona grandis*). Table 1 summarizes the landuse in Wonogiri and Ponorogo.

Survey Procedure

A multi-stage purposive sampling method was used to select respondents representing the four categories of seed agents—seed companies, seed

Table 1 Landuse in Wonogiri and Ponorogo

Land use	Wonogiri		Ponorogo	
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Rice field	30,701	16.8	35,000	25.6
Dry land farming	61,011	33.5	30,908	22.6
Home garden	36,026	19.8	20,926	15.3
Community forest	12,879	7.1	–	–
State forest	16,268	8.9	46,990	34.3
Other	25,351	13.9	3,154	2.3
Total land area	182,236	100	136,978	100

Source: BPS Ponorogo (2000) and BPS Wonogiri (2000)

middlemen, seed assemblers and seed collectors—involved in the Wonogiri–Ponorogo tree seed pathways. These four categories were identified based on observation and discussion with individuals involved or familiar with the tree seed trade. Ten local seed companies and middlemen were identified from a list of national tree seed supplier compiled by ICRAF, Winrock International, the Danida-funded Indonesian Forest Seed Project (IFSP), and the Directorate of Forest Tree Seed (DFTS) of the Ministry of Forestry. The seed companies and middlemen selected were those with the largest volume of seed sold annually and that operate at the national level. A snowball sampling approach was used to trace direct linkages between seed companies and other agents in the pathways. Information from seed companies and middlemen was used to identify local seed assemblers. Seed collectors were identified based on information provided by local assemblers and seed companies. The seed assemblers selected were those who play a vital role in helping seed companies and middlemen achieve their seed orders. The seed collectors selected were those who are reliable in meeting seed collection targets. A total of 71 respondents were interviewed, including 7 seed companies, 3 middlemen, 11 seed assemblers and 50 seed collectors. The distribution of respondents by district is listed in Table 2. The survey includes the seven largest seed companies in Indonesia, and all the major seed companies and seed middlemen in the Wonogiri–Ponorogo area which account for most of nation's tree seed trade, thus results accurately reflect the tree seed sector. However, the tree seed collectors surveyed represents less than 1% of the individuals engaged in tree seed collection in the Wonogiri–Ponorogo area.

The survey was conducted in late 2001 and early 2002, and collected data for the seed year 2001 using a semi-structured questionnaire. Data were collected on the topics of: socioeconomic condition of respondents; source of seed; seed collection, processing, handling and storage procedures; quantity of seed procured and sold annually; priority species as indicated by seed volume; seed flow between seed agents and customers; and income generated from seed procurement and diffusion activities. The questionnaire was developed by the authors through an iterative process, including review by ICRAF colleagues. Field testing indicated no problems with or changes required in the questionnaire. Interviews were conducted in Bahasa Indonesia by a native speaker. No communication problems occurred between the interviewer and the respondents.

Table 2 Distribution of respondents interviewed by district

Seed agent	Wonogiri	Ponorogo
Seed companies	4	3
Seed middlemen	1	2
Local seed assemblers	4	7
Seed collectors	28	22
Total respondents	37	34

Survey Findings

Survey findings are summarized below according to the following topics: socioeconomic profiles of seed agents; details of tree seed pathway linkages; seed quantities, flow and customers; seed sources, mother trees and collection methods; seed processing, shipping and documentation; principal species; and financial impacts of tree seed trade on seed agents.

Profiles of Seed Agents (Companies, Middlemen, Assemblers and Collectors)

The four types of seed agents vary greatly in terms of socioeconomic profile. Farmer collectors were 26 to 65 years old, with an average age of 42 years. The highest level of education of 94% of the farmer collectors was primary schooling. The farmer collectors owned insufficient land to support their families, 96% owning less than 0.5 ha, and hence relied on seed collection to supplement their incomes. Seed assemblers were 36 to 56 years of age. For 64%, the highest level of education was primary schooling, the remainder having intermediate or high school education. Most had insufficient landholdings to support their families; 64% had less than 0.5 ha and 27% had 0.5–1.0 ha. Seed middlemen were 45–51 years of age. Their education level was similar to assemblers, 67% having a primary school education and 33% a high school education. Middlemen owned an average of 3 ha and all were either district or village officials with strong links to local seed and seedling customers. Seed company owners were 56–65 years old and all had a high school or university education. They had large landholdings—57% owned 5–10 ha and the remainder owned an average of 3 ha—and 86% were district or village officials.

Pathway Linkages

Farmers sold 54% of the seed collected to companies and 46% to assemblers. Eighty percent of the seed purchased by assemblers was sold to seed companies and 20% to middlemen. Companies sold 24% of their seed to other companies or middlemen, the remainder being sold to seed customers (government agencies, state companies, private companies, development projects, private nurseries, farmers, and NGOs). Middlemen sold 100% of their seed to customers. Farmers sold some tree seed to customers in local markets, and assemblers occasionally sold seed directly to customers, but only limited volumes of seed were sold through these two channels. Figure 1 depicts linkages between Wonogiri–Ponorogo seed agents and the volumes of seed exchanged.

Seed Quantities, Flow and Customers

Seed suppliers (companies and middlemen) estimated they procure and sell 1,510 tons of tree seed annually. About 24% of this total (362 tons) is exchanged between suppliers. Of the 1,148 tons sold to seed customers; 72% (826 tons) is collected by farmers in the Wonogiri–Ponorogo area; 24% (275 tons) originates

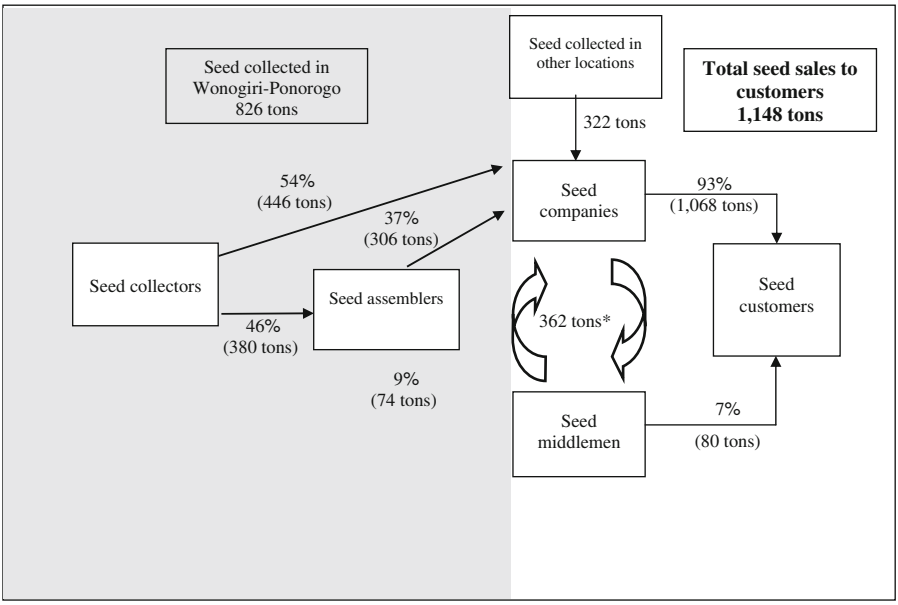

Fig. 1 Tree seed procurement and diffusion pathways in the Wonogiri–Ponorogo area

from Sumatra; 3% (35 tons) is imported from Madura; and less than 1% is from Nusa Tenggara. The Wonogiri–Ponorogo seed is primarily of naturalized exotic tree species. The Sumatra seed is of cover crop species.[2] The Madura seed is exclusively *L. leucocephala* and the Nusa Tenggara seed is of various tree species. Once processed 28.3% (325 tons) of the seed is sold to customers in Kalimantan; 20.5% (236 tons) to Sulawesi; 18.7% (215 tons) to Sumatra; 17.4% (200 tons) to Irian Jaya; 9.6% (110 tons) to other locations in Java; 4.5% (52 tons) to Nusa Tenggara; 0.5% (6 tons) to Bali; and 0.4% (5 tons) is exported internationally. District Forest and Estate Crop Offices purchase 46% of the seed; state forest companies 29%; other state and private companies (including development projects and firms implementing projects) 20%; private nurseries 3%; farmers 2%; and NGOs 0.7%. Figure 2 illustrates the flows of seed in and out of Wonogiri–Ponorogo area.

Seed Sources, Mother Trees and Collection Methods

Forty-four percent of farmer seed collectors collect seed exclusively from state plantations; 36% collect seed exclusively from farmland; and 20% collect from both state plantations and farmland. Seed collectors select mother trees according to a limited set of criteria. Tree accessibility and the presence of abundant mature seed crops are the key criteria, used by 90% and 78% of farmer collectors, respectively. Sixty-six percent of farmers collect seed from tall (mature) trees, regardless of tree health or phenotypic quality. Only 8% of seed collectors select mother trees that are

[2] These species are planted to prevent erosion and provide green manure.

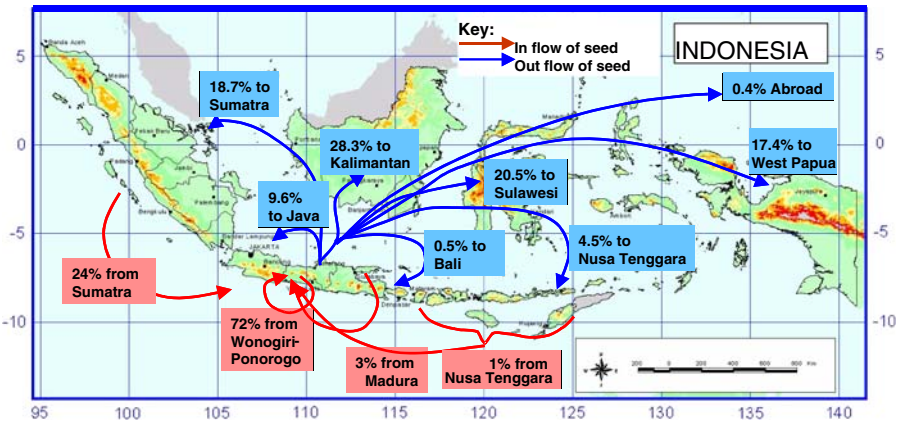

Fig. 2 Tree seed flows in and out of the Wonogiri–Ponorogo area

free of pests and diseases, and only 4% select mother trees according to phenotypic characteristics for timber quality. Individual farmers collect seed from 2 to 5 trees per day. Over the entire season 68% of farmers collect seed from 40 to 200 trees, 12% from 20 to 40 trees, and 20% from less than 20 trees. Only 4% of collectors select mother trees that are 100 m apart. Regarding seed selection criteria, 80% of collectors select mature seed, 74% select fruit that are full of seed, 6% select seed that is free of pests and diseases, 4% select relatively large seed, and 4% select dry seed. Table 3 provides a summary of mother tree and seed selection criteria. Eighty percent of farmers collect seed directly from trees; 20% collect seed from the forest floor; and 18% collect seed from both trees and the forest floor. Pole pruners and hooked bamboo poles are used to collect seed from trees. However, no tree climbing safety equipment is used, nor are tarps used to facilitate the gathering of fallen seed.

Seed Processing, Shipping and Documentation

After collection, green fruits are stored in sacks for 1–2 days to after-ripen. Fruit processing and seed cleaning requires 1–2 days, after which the seed is sun dried for 1–2 days. Processing (extraction, cleaning, drying and sorting) reduces seed volume by 5–10% for most species, though by 20% for some species (including *L. leucocephala*, *G. arborea*, *Tephrosia candida*, *Pinus merkusii*, *Anacardium occidentale* and *Dalbergia* sp.) and as much as 20–50% for *S. macrophylla*.[3] Seed is normally shipped to customers within 1–14 days of processing. Most seed is shipped in sacks, shipments intended for destinations outside of Java being double-sacked. Large shipments are delivered to customers by seed company trucks; costs are Rp 950,000 per truck within Java and Rp 2.5–3.5 M per truck to Sumatra.[4] Smaller shipments are sent through shipping services. Shipments are usually

[3] The amount of debris and moisture lost varies between species.

[4] $1 US = 9000 Indonesian Rupiah approximately, as at October 2007.

Table 3 Mother tree and seed selection criteria used by farmer collectors

Seed tree selection		Number of seed trees		Seed collection	
Criterion	Proportion of farmers (%)	Seed trees	Proportion of farmers (%)	Criterion	Proportion of farmers (%)
Easy to reach	90	<20	20	Mature	80
Abundant seed	78	20–40	12	Full seed	74
Tall trees	66	40–60	14	Free of pests and disease	6
Free of pests and disease	8	60–100	22	Large size seed	4
High timber quality	4	100–200	20	Dry seed	2
		>200	12		

delivered in 1–2 days in Java and 3–6 days outside of Java. Very small shipments and high value seed are sent by courier service, overnight in Java and within a few days outside of Java. Customers are charged for shipping and courier service at cost. Generally, no seed documentation (e.g. information regarding seed source, seed lot purity or viability) is provided with shipments.

Principal Species for Which Seed is Collected

Suppliers procure and sell germplasm of 71 species. Their primary product is seed, the key species for which are listed in Table 4. Cover crop species, *Gmelina arborea*, *Tectona grandis* and *Leucaena leucocephala* account for the 84.6% of the total seed volume sold. Seed of indigenous species accounts for less than 1% of the seed sold. Suppliers also sell approximately 500,000 seedlings per year, the key species for which are identified in Table 5. *Cocos nucifera*, *Eugenia aromatica*, *Nephelium lappaceum*, cover crops and *Swietenia macrophylla* account for 66% of the seedlings sold.

Seedlings produced under contract are mainly of horticultural species that require a long production period. Seed sales focus on exotic timber and leguminous tree species, the main components of government land rehabilitation programs. Cover crops and *S. macrophylla* are commonly sold as both seed and seedlings. *Leucaena leucocephala*, *T. grandis*, *G. arborea* and cover crops are the most profitable species due to their use in government programs. Seed of those species are sold in large quantities, accounting for 92% of seed company income. Estimated profits margins—defined as ((sale price − purchase price)/purchase price) × 100—for individual species vary from 1233% (*Melaleuca leucadendron*) to 17% (*Albizia saman* and *Prosopis* sp.). Species with profit margins of 100% or above are *Acacia arabica*, *Acacia mangium*, *Acacia oraria*, *Acacia tomentosa*, *Azadirachta indica*, *Calliandra calothyrsus*, *Ceiba petandra*, *Dalbergia latifolia*, *Leucaena leucocephala*, *Melaleuca leucadendron*, *Mucuna pruriens*, *Senna siamea*, *Shorea* sp., *T. grandis* and *Tamarindus indica*. Species with a high seed value (Rp per kg) are *A. mangium*, *A. oraria*, *D. latifolia*, *M. leucadendron*, *Pinus merkusii*, *Prosopis* sp.,

Table 4 Principal species of seed sold by Wonogiri–Ponorogo suppliers

Species	Share of seed volume (%)	Species	Share of seed volume (%)
Cover crops[a]	25.0	*Gliricidia sepium*	2.7
Gmelina arborea	24.1	*Swietenia macrophylla*	2.6
Tectona grandis	20.1	*Calliandra calothyrsus*	2.4
Leucaena leucocephala	15.4	*Paraserianthes falcataria*	1.0
Aleurites moluccana	4.4	Indigenous tree species	>1
		Total	97.7

[a] The cover crops are mainly *Centrocema pubescens*, *Calopogonium* sp., *Crotolaria mucronata* and *Mucuna pruriens*

Table 5 Principal species of seedlings sold by Wonogiri–Ponorogo suppliers

Species	Share of seedling numbers (%)	Species	Share of seedling numbers (%)
Cocos nucifera	20.6	*Gnetum gnemon*	7.9
Eugenia aromatica	12.1	*Citrus* sp.	6.1
Nephelium lappaceum	12.1	*Parkia speciosa*	5.3
Cover crops[a]	11.1	*Mangifera indica*	5.1
Swietenia macrophylla	10.1	*Aleurites moluccana*	4.0
		Total	94.4

[a] Cover crops included *Mucuna* sp. (4.0% of seedlings) and *Tephrosia candida* (7.1% of seedlings)

T. indica and *S. siamea*. Table 6 provides purchase and sale prices for the seed of key species as reported by Wonogiri–Ponorogo seed companies

Financial Impacts of Seed Pathways

Based on reported volume of seed sold, suppliers' annual revenues less seed procurement and processing costs vary from Indonesian Rupiah (Rp) 22 M to Rp 765 M (US $2600 to $90,000). Total annual revenues for all Wonogiri–Ponorogo seed suppliers surveyed are Rp 2.4 billion (US $280,000). These revenue estimates do not consider fixed costs (such as vehicles, property rents, maintenance costs, miscellaneous equipment and supplies, daily operating expense, wages and salaries for family employees), depreciation and some other expenses. Seed companies employ 2–4 permanent and 4–20 part-time workers. Estimates indicate that as a group these employees earn approximately Rp 55 M (US $6500) annually from processing seed, averaging Rp 330,000 to Rp 525,000 per employee (US $39 to US $62). Farmer collectors estimate that they earn Rp 275,000 to Rp 795,000 (US $32 to US $94) from seed collection during the annual 3-month dry season. Sixty-six percent of farmer collectors earn at least 33% of their dry-season income from seed collection; 24% earn 34% to 50% of their dry-season income; and 10% earn 66% or more of their dry-season income.

Table 6 Purchase and selling price for seed of key species (Rp/kg)

Species	Purchase price	Selling price	Species	Purchase price	Selling price
Acacia arabica	1,750	4,000	*Gliricidia sepium*	1,950	3,000
Acacia auriculiformis	3,500	5,000	*Gmelina arborea*	4,500	6,500
Acacia mangium	5,000	17,500	*Leucaena leucocephala*	2,100	9,500
Acacia tomentosa	2,500	6,000	*Melaleuca leucadendron*	3,000	40,000
Acacia oraria	5,000	14,500	*Melia azedarach*	2,000	3,500
Acacia villosa	2,500	3,750	*Mucuna pruriens*	1,750	4,000
Albizia saman	1,500	1,750	*Paraserianthes falcataria*	4,000	6,000
Albizia procera	3,000	5,000	*Pinus merkusii*	37,500	50,000
Azadirachta indica	1,600	5,250	*Prosopis* spp.	30,000	35,000
Caesalpinia sappan	2,000	2,500	*Schleichera oleosa*	3,700	8,000
Calliandra calothyrsus	4,000	8,000	*Senna siamea*	5,000	12,500
Ceiba petandra	500	1,750	*Sesbania grandiflora*	2,000	2,750
Crotalaria mucronata	1,650	2,000	*Shorea* spp.	3,000	8,000
Dalbergia latifolia	2,500	12,000	*Swietenia macrophylla*	3,000	5,000
Dalbergia sisso	2,000	3,500	*Tamarindus indica*	1,000	10,000
Enterolobium cyclocarpum	2,750	4,500	*Tectona grandis*	1,400	3,500
Eucalyptus alba	2,000	3,500	*Tephrosia candida*	5,000	7,000

Discussion

Farmer collectors, seed assemblers, seed middlemen and seed companies conduct the activities (collection, procurement, transport, processing, storing, selling) and provide the inputs (labour, skills, information, capital) needed to move seed through the Wonogiri–Ponorogo pathway from trees to customers. Agents are progressively older, better educated and more economically secure at each step along the pathway from collector to company owner. This progression coincides with market power along the seed pathway.

Seed companies operate as family businesses and are the dominant pathway agent. They facilitate most of the activities and inputs required. Companies are responsible for seed processing, a key value-adding activity, that enables them to gain an additional profit margin. Companies protect their dominant role by maintaining strong linkages with farmer collectors and assemblers (procurement networks), and strong linkages with customers at local, provincial, national and international levels (diffusion networks). Their primary customers are government organizations that purchase large quantities of seed, but they also readily fill small orders from other customers. Middlemen play a simpler role, transferring seed from other agents to customers without increasing seed value. Middlemen maintain strong linkages with local government customers which enables them to capture profit. Seed assemblers do not operate independently. They generally work for a single company or middleman. Assemblers may collect seed themselves, but their

main role is to facilitate networks of farmer collectors. When procuring seed for middlemen, assemblers are able to capture more of the price margin by processing seed. Farmers are in the weakest position in the pathway. They collect seed and accept the price offered by assemblers and companies. The linkages, activities and inputs of the various seed pathway agents are depicted in Fig. 3.

The annual seed procurement–diffusion process starts when orders are received by suppliers from customers, usually between July and September; some orders are received as late as December. Most seed is collected July through September. Companies and assemblers operate in specific territories. All companies and assemblers recognize the existence of these seed procurement territories. If one company or assembler has an established operation in a village, other companies and assemblers generally will not purchase seed directly from farmers at that location. On occasions when a company's network of seed assemblers and collectors is not able to fill orders, the company purchases the shortfall of seed from other companies or other assemblers. Prices depend on market conditions and personal relationships between buyer and seller, but generally are higher than the company would pay to assemblers or collectors in its own territories. The recognition of these seed territories operates as a trade syndicate, limit farmers' options and allow companies to set seed prices. Occupying weaker positions in the pathway, assemblers and middlemen generally follow the price range set by companies. The prices set by companies are greatly influenced by government customers who purchase over 75% of seed volumes. Government customers are typically highly price sensitive, showing a preference for large quantities of inexpensive seed.

Agents	Collectors	Assemblers	Seed companies	Middlemen	Customers
Linkages		Collect	Collectors, Assemblers, Customer	Customers	
Activities	Collection Processing Transport	Processing (minimal)	Procurement Transport Processing Storage Selling	Procurement Selling	Purchase
Inputs	Labour Skill	Information	Labour (employees) Skills Information Capital	Information	

Fig. 3 Linkages, activities, and inputs of the various agents involved in the Wonogiri–Ponorogo tree seed pathway

Most farmers receive orders before collecting seed, only 32% collecting seed on their own initiative in anticipation of annual demand. Farmers collect seed from both state forestland and farmland. Permission is generally sought from land managers or owners before seed is collected. There is little information available concerning the origins of the seed used to established the secondary forests used as seed sources. As with all undocumented seed, it is assumed to have a narrow genetic base. This study reveals that farmers' seed collection practices show little appreciation for genetic quality. Farmers typically select seed sources and mother trees that are close to each other, easy to access and have abundant seed crops. They collect seed from as few trees as possible. The sheer volume of seed collected in Wonogiri–Ponorogo (and by individual farmer collectors) assures it comes from a large number of unrelated trees in widely dispersed locations. As such, it is reasonable to assume that significant narrowing of the genetic base is not occurring. More worrying, for the wider-industry, is the disregard by seed collectors of the importance of tree quality as a key criteria for seed source and mother tree selection. Collectors' preference for seed quantity over seed source or mother tree quality indicates negative selection criteria and is driven by the nature of the market and seed buyer preferences. Seed buyers are concerned mostly with seed quantity and price, not seed quality. They generally do not require farmers to collect seed according to technically sound guidelines.

Findings in Wonogiri–Ponorogo are similar to those in the Philippines (Koffa and Roshetko 1999) and indicate that time constraints, a lack of knowledge regarding proper seed collection guidelines, and negative incentives (quantity over quality) result in farmers adopting poor seed collection practices. Seed collection guidelines developed for farmer-specific conditions stress selecting high quality seed sources and mother trees, and collecting from a minimum 30 trees that are at least 50 m apart (Dawson and Were 1997; Mulawarman et al. 2003). These guidelines are simple and farmers can readily adapt them to their situations. They assure seed is collected from an adequate number of best quality trees in a population and increases the chance that the seed represents broad genetic diversity (unrelated parents). By comparison, current practices indicate that the seed collected is of average to below-average genetic quality.

Studies in the Philippines show that farmers who demonstrate poor seed collection skills can develop technically sound seed collection practices following training (Carandang et al. 2006; Catacutan et al. 2006; Koffa and Garrity 2001; Koffa and Roshetko 1999). Farmers report the above mentioned guidelines are applicable to their conditions, easy to implement and require little additional time or effort on their part. A strong demand for tree seed, a commitment to collect high quality seed and a reputation as suppliers of high quality seed encourage farmers to adapt recommended tree seed collection methods (Koffa and Garrity 2001). Experience with farmers and NGOs in Indonesia yield similar conclusions to those of the Philippines (Roshetko 2002).

When seed demand or price for a particular species is high and few local sources exist, Wonogiri–Ponorogo companies have established seed sources. One company provides farmers with seed, fertilizers and wages to produce seed of cover crop species under contract. Those cover crop species produce seed within a year,

providing companies and farmers with a quick return on investment. Most companies have planted stands of trees on their own land, through government land rehabilitation programs, that function as seed sources. These stands provide only a fraction of the seed collected by companies, but demonstrate a long-term seed procurement strategy.

The most interesting case of local seed source establishment involves *E. cyclocarpum*, which was a major component of the national regreening program in the 1980s. With seed demand high and few seed sources within the country, seed price was a lucrative Rp 60,000/kg (US $30 at the time). A supplier rented farm land to establish stands of *E. cyclocarpum* with support from the national rehabilitation program. Farmers were encouraged to intercrop the *E. cyclocarpum* stand and retain ownership of the *E. cyclocarpum* seed crops. The supplier has first rights to purchase the seed. Both farmers and the supplier benefit from this relationship, a unique example of private sector and farmer collaboration utilizing the national reforestation program to establish tree plantations for the specific long-term objective of seed production. The production of large quantities of *E. cyclocarpum* seed begins when trees are 25 years old (Hughes and Stewart 1990), and the *E. cyclocarpum* seed sources have only recently reached high production.

To reduce the weight of the seed carried home, farmer collectors initiate seed extraction and cleaning of species that are easily processed including *L. leucocephala*, *T. grandis*, *S. macrophylla* and *C. calothyrsus*. For these species field processing (partial extraction and cleaning) activities are considered part of the collection process, for which collectors receive no additional payment. The amount of seed that can be collected per day varies greatly by collector, tree species and conditions of the seed source. Collectors and assemblers offered the following generalization, for which there are many exceptions: *T. grandis*—1 sack (20–25 kg) collected per day; *S. macrophylla*—1 sack (10 or more kg) collected per 3–5 days; *Leucaena*, *Gliricidia* or *Calliandra*—3–5 kg collected per day.

Companies conduct seed processing by employing local farmers on a daily wage or contract basis. Daily wages are Rp 7,000 for female workers and Rp 10,000 for male workers to clean, dry and sort 100–200 kg per day or pack and store 200–500 kg per day. Contract wages average Rp 15,000 per ton to clean, dry and sort and Rp 7,500 per ton to pack and store regardless of gender. The apparent differences between daily and contract rates are misleading, because the former is more leisurely. Through diligent effort workers can easily clean and sort 1 ton per day or pack and store 2–3 tons per day. Contract rates are paid per tompo, a traditional volume unit of just over 4 kg. In practice, companies calculate a tompo as 4 kg, claiming that the small advantage gained with each tompo compensates for the 10–20% loss in seed volume resulting from processing. Employees are aware of the volume discrepancy, and accept the condition because they are satisfied to have employment that suits their circumstances. With the exception of *T. grandis*, seed is not graded because no premium is paid for higher quality seed. If higher quality is requested, companies will grade seed and increase the price to cover their cost.

Seed is shipped to customers as soon as possible. In general, shipments are not accompanied by seed quality documents. One company surveyed does provide technical information on seed pre-treatments, seed sowing and seedling care. If

customers request seed documentation some companies provide letters from Regional Forest Tree Seed Centers (BPTH, Balai Perbenihan Tanaman Hutan) certifying that seed samples from the company have been tested for purity and viability. Such letters are largely perfunctory; no guarantee is implied and customers have no recourse if seed quality does not match that indicated. National tree seed certification procedures and regulations are currently under development by the Directorate of Forest Tree Seed, Ministry of Forests (DGLRSF 2002).

All companies have facilities to store seed that is not sold immediately. These facilities consist of cement rooms or wooden structures. Conditions are generally clean, cool, dry, well-ventilated and well-lit, and protect seed from direct sunlight. Seed is stored in burlap or plastic sacks, bamboo baskets, boxes or other containers, and is stacked on shelves, pallets or directly on the floor. Sacks placed on the floor degrade more quickly from pests, moisture and physical damage. These storage conditions are adequate for periods up to 12 weeks. For most species, if seed is not sold after 6 months companies employ one of the following measures: (1) seed is redried and sorted (low quality seed is burned and the satisfactory quality seed is sold the following year); (2) seed is sold to make medicine (*S. macrophylla*), mosquito repellent (*A. indica*), or other products, and unsold seed is burned; (3) seed is stored until the following year, when it is mixed with new seed at a rate of 1 to 10 and sold. Long-term storage (over 6 months) of high-value seed is achieved by using sealed glass jars wrapped in cotton cloth or sending seed to the BPTH in Bandung for cold storage.

Seed collection and processing activities are dominated by women. Forty-eight percent of seed collector respondents are female farmers; the other 52% are husband and wife teams. None of the male respondents are active in seed collection without the partnership of their wives. There are clear job divisions between men and women's seed collection roles. Men climb trees, directly collect seed or knock it to the forest floor, where women collect the seed and discard the debris. Women collect seed directly from short and medium stature trees without climbing. Husband and wife pairs collect seed from *L. leucocephala*, *S. macrophylla*, *E. cyclocarpum* and *P. falcataria*. Women collect the seed of *G. sepium*, *T. grandis*, *G. arborea*, *Albizia* sp. and *Acacia* sp. without assistance. Men carry the seed home from the forest and perform other tasks requiring heavy lifting. Seed processing activities—seed extraction, cleaning, drying, and sorting—are conducted primarily by women. Survey data indicate that a minimum of 75% of the seed collection and processing is conducted by women. Running the seed companies is also the domain of women. The wives of the owners manage six of the seven seed companies surveyed. These women are responsible for the development and maintenance of relationships with farmer collectors and assemblers; the placement of orders with collectors and assemblers; the organization and monitoring of seed processing; the management of permanent and part-time employees; and the organization of seed deliveries. The husband–owners develop and maintain the important linkages with customers. All the seed assemblers and middlemen in Wonogiri–Ponorogo are men.

Wonogiri–Ponorogo suppliers sold 1149 tons of tree seed to customers across Indonesia in 2001 and dominate the national tree seed market. One hundred

twenty-eight enterprises are listed in Indonesian directory of tree seed suppliers (Roshetko et al. 2003). The seven largest suppliers are located in Wonogiri–Ponorogo. They reported that they have the capacity to supply between 50,000 and 300,000 kg of seed per year. This capacity is in addition to anticipated annual orders from established customers. The largest suppliers outside the Wonogiri–Ponorogo area report capacities of only 10,000 kg per year. The average capacity of these non-Wonogiri–Ponorogo suppliers is 2,200 kg per year. A survey in Nusa Tenggara found that 15 NGOs are involved in the tree seed trade directly or through partner farmer groups, with a total capacity of 1,600 kg per year (Harum et al. 2006). Data provided by Indonesian seed suppliers indicates that Wonogiri–Ponorogo suppliers possess 80–90% of the national tree seed supply capacity. Discussions with non-Wonogiri–Ponorogo suppliers indicate they primarily sell seed at the local or provincial level. Several Indonesia-based forest industries and research organizations produce improved-quality seed of a limited number of tree species, including *A. mangium*, *T. grandis*, *S. macrophylla*, *P. falcataria*, *G. arborea*, *G. sepium*, *Pinus merkusii* and eucalypt species (Ochsner et al. 2004; DGLRSF 2003). This improved-quality seed is of limited quantity and is expensive. It is primarily sold or exchanged within the formal tree seed sector, including research organizations, government agencies and forest industries. This pattern of reserving improved-quality seed for the formal tree seed sector is common in Southeast Asia (Harwood et al. 1999).

Seed collection and sales generate substantial income for all agents involved in the Ponorogo–Wonogiri tree seed pathway. Most companies will procure seed or seedlings of any species requested by customers. Middlemen are generally only interested in large orders. As the dominant agent type which facilitates the most activities and inputs, seed companies receive the greatest financial benefits. Based on the reported quantities of seed sold, seed company annual revenues less procurement and processing costs are Rp 22 M to 765 M. Seed companies also incur costs for vehicle operation, property rents, maintenance of facilities, miscellaneous equipment and supplies, labour (wages and salaries for family employees and casual employees) and depreciation. Additional expenses are extra-legal fees involved with selling and transporting seed.

Seed companies are family-operated businesses, and records or estimates of these costs are not kept or are not available to outsiders. Seed companies consider the seed trade to be a risky business, and feel they are at a clear disadvantage in all transactions. Their main customers—government agencies—order large volumes of seed but provide no advance payments. Companies have to pay collectors and assemblers for seed on delivery, and make further investments in processing, packaging and shipping. If orders are cancelled companies have no recourse, even when seed has been collected and processed or purchased from other suppliers. Payments are often late or never received. Government officers who order and use the seed may be transferred to new assignments before payment is processed. Newly arrived officers feel no obligation to pay for past activities from their current budgets. It is imperative that companies maintain close relationships with their government and corporate customers. Despite the perceived risks, profits are attractive, and no seed companies were considering leaving the business.

Middlemen occupy a strategic linkage between seed supply and customers. This position enables them to capture profit without incurring large investments or recurrent financial outlays. To protect their market position, middlemen are not forthcoming with details concerning their relationships with customers. Middlemen consider the seed business to be profitable. In Nusa Tenggara, some local NGOs operate tree seed enterprises to support their agroforestry activities and enhance local livelihoods. Incomes from tree seed sales offset NGO operational expenses. Fifteen NGOs reported a total gross annual income of Rp 36 M (Harum et al. 2006). Those NGOs mainly sell seed to other NGOs, farmers and projects. They are also in a strategic position to sell seed to local government agencies, but these agencies usually buy seed through Wonogiri–Ponorogo seed companies.

The financial benefits gained by assemblers are difficult to quantify. Payments received by assemblers are calculated in various ways. Assemblers may receive a nominal Rp 500/kg collected or a fee of Rp 10,000/100 kg seed. Sometimes they are paid a finder's fee of Rp 10,000–20,000 per seed source for identifying and facilitating collection locations. The same source might be 'identified' in more than 1 year. If the supply of seed organized by an assembler is particular profitable, a company may give them a television set or similar gift. In general, assemblers are content with their role in the seed pathway, which is only one of their income-earning activities. Forty-five percent of assemblers also market spices and furniture, performing a role similar to their function in the seed pathway.

Farmer collectors are the most numerous seed agent in Wonogiri–Ponorogo, though little data about them are available. Several survey respondents reported that in some Wonogiri–Ponorogo villages nearly all adults are involved in tree seed collection activities. One company estimated it employs 450 farmers annually to collect seed. Extrapolation indicates that each year 22,500 farmers may be involved in seed collection activities in Wonogiri–Ponorogo. Tree seed collection occurs from July through to September in the dry-season when agricultural activities and other economic options are limited. Farmers are available and eager to collect tree seed to increase their incomes. This large willing labour force and the collusive practice of exclusive seed procurement territories enables seed companies to control the price paid to farmers. If farmers demand a higher price, company representatives and assemblers simply approach other farmers to collect seed. Several farmers commented that before seed companies began operating tree seed had no value. Now it is a valued commodity that augments local incomes, providing 33% to 66% of farmer collectors' dry-season income (Rp 275,000 to Rp 795,000). Processing seed is equally lucrative for farmers living near seed companies, providing Rp 330,000 to Rp 525,000 per employee per dry-season. About 135 farmers are employed annually by companies to process seed.

The cash earned from seed collection and processing is controlled by household women and earmarked for a number of specific purposes. All families surveyed prioritize the use of seed-related income to provide daily food needs during the dry-season and to support social commitments, including weddings, funerals, circumcisions or other community donations. In half the respondent families, the remaining seed-related income is invested in cattle as a form of a living bank account. As cattle grow they accrue value and are sold whenever cash is required, commonly to

purchase agricultural inputs or cover family emergencies. Alternatively, when cattle prices are high, they are sold and gold purchased as a new form of savings. Some seed-related income is allocated to provide children with pocket money or to cover regular medical expenses.

Conclusion

Wonogiri–Ponorogo seed suppliers represent only 9% of the suppliers operating in Indonesia; however, they possess 80–90% of the national tree seed supply capacity and are clearly the main source of tree seed in Indonesia. They procure an estimated 1,510 tons of tree seed annually. About 24% of this total is exchange between them. Of the 1148 tons sold to seed customers in the survey year, 72% (826 tons) was collected in the Wonogiri–Ponorogo area, 24% (275 tons) in Sumatra, 3% (35 tons) in Madura, and less the 1% in Nusa Tenggara. Most of the seed is sold to local, provincial and national customers across Indonesia. Typically, about 5 tons (0.4% of the total in the survey year) is sold abroad. Government agencies purchase more than 75% of the seed and thus have a strong influence over price and species of seed collected. The main species for which seed is sold are naturalized exotic timber species and leguminous tree species, which are popular components of government land rehabilitation programs.

A locally-evolved system of seed collectors, seed assemblers, middlemen and seed companies conducts seed procurement and diffusion activities in Wonogiri–Ponorogo. Assemblers organize seed collection by farmers for companies and middlemen, who sell the seed to customers. Seed companies facilitate or provide most of the activities and input required to move the seed from the forest to the customers. They are the dominant agent in the Wonogiri–Ponorogo tree seed pathway. The seed is collected from state plantations and farmland.

Little information is available concerning the genetic origins of the secondary forests which function as seed sources. Genetic studies would be useful to document the existing diversity. Farmers collect seed from trees that are close to each other, easy to access and have abundant seed crops, without regard for the quality of the tree. Fortunately, the sheer volume of seed collected in Wonogiri–Ponorogo assures that it comes from a large number of unrelated trees over widely dispersed locations. More worrying is farmer collectors' disregard of tree quality as an important criterion for mother tree selection. Standard seed collection practices, which indicate negative selection criteria—with seed collected from trees that are easy to access rather than phenotypically superior, are driven by the nature of the market. Seed buyers are primarily concerned with large quantities of inexpensive seed, rather than high seed quality. Evidence indicates that simple seed collection guidelines developed for local conditions can help improve farmer's seed collection practices and the genetic quality of seed collected. A commitment to high seed quality by all agents and customers is required to make such guidelines functional and acceptable.

Seed collection and processing methods in Wonogiri–Ponorogo rely on low-technology that is adequate. Women are indispensable to seed procurement–

diffusion in Wonogiri–Ponorogo. They conduct 75% of the seed collection and processing activities and are responsible for the daily management of most of the seed companies. Seed procurement and sales generate substantial benefits for all agents. Suppliers earn revenues of Rp 22 M to Rp 765 M (US $2600 to US $90,000), excluding fixed costs, depreciation, extra-legal fees and non-payment. An estimated 22,500 farmers are involved in seed collection activities annually, earning an average of Rp 275,000 to Rp 795,000 ($32 to $94) a year, which equals 33–66% of their income during the 3-month seed collection season. Seed processing is also a lucrative activity for farmers living near seed companies, providing Rp 330,000 to Rp 525,000 per person during the dry-season.

The prominent role of Wonogiri–Ponorogo seed suppliers in the national tree seed supply system is likely to continue because the government agencies responsible for land rehabilitation program have established linkages with these suppliers and the species required match those available. Other regions of the country do not possess the advantageous geographic location or expansive secondary forests of appropriate species to serve as a major source of tree seed for the country. However, there is potential for provincial-level seed suppliers to assume a larger role in supplying tree seed to local customers, including local government offices, locally-based projects, NGOs and farmer groups—all of whom face annual shortage of tree seed. Local government offices in particular could help strengthen provincial-level seed suppliers when seed of appropriate species is available locally.

Policy Implications

Based on the findings of this study, a number of policy implications can be drawn to help enhance the quality, quantity and accessibility of tree seed available to seed users in Indonesia. There is a role for government agencies, which purchase 75% of the tree seed sold by Wonogiri–Ponorogo seed companies, to require seed companies to collect, handle and store tree seed according to technically sound guidelines. Wonogiri–Ponorogo based seed companies, which supply most of the tree seed traded at the national level, would benefit from capacity-building training to enhance their awareness and understanding of tree seed quality. The simple tree seed collection guidelines developed by ICRAF, Winrock, BPTHs and ISFP (Mulawarman et al. 2003) have proven appropriate for local conditions in Indonesia and should be used to train the tree seed companies and seed assemblers involved in the Wonogiri–Ponorogo tree seed pathways. Once trained, seed companies and seed assemblers could then instruct or train their network of farmer collectors how to properly collect tree seed.

In that women play significant role in seed collection and processing, there is a case for specifically targeting women for training by seed companies and seed assemblers. Notably, ICRAF and Winrock have developed a mini-training course for implementation at the village level that allows women to attend the multi-day training while also satisfying their household responsibilities.

A recommendation from the research is that seed sources be identified and certified for the principal species for which seed is collected in the Wonogiri–

Ponorogo area. It is also suggested that a form of joint land access and management between government land management agencies and local farmer collectors be developed to facilitate improved management of seed sources and mutual benefit to all involved parties.

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References

BPS (Badan Pusat Statistik) Ponorogo (2000) Ponorogo dalam angka (Ponorogo in figures). Badan Pusat Statistik Kabupaten DATI II Ponorogo, Jawa Timur, Indonesia

BPS (Badan Pusat Statistik) Wonogiri (2000) Wonogiri dalam angka (Wonogiri in figures). Badan Pusat Statistik Kabupaten DATI II Wonogiri, Jawa Tengah, Indonesia

Carandang WM, Tolentino EL Jr, Roshetko JM (2006) Smallholder tree nursery operations in southern Philippines—supporting mechanisms for timber tree domestication. For Trees Livelihoods 16:71–83

Catacutan D, Bertomeu M, Arbes L, Duque C, Butra N (2006) Fluctuating fortunes of a collective enterprise: the case of the Agroforestry Tree Seeds Association of Lantapan (ATSAL) in the Philippines. Paper presented at the international workshop on collective action and market access for smallholders. Held 2–6 October 2006, in Cali, Colombia

Cromwell E (1990) Seed diffusion mechanisms in small farmer communities: lessons learned from Asia, Africa and Latin America. Network paper no. 21. Overseas Development Institute, London

Cromwell E, Friis-Hansen E, Turner M (1992) The seed sector in developing countries: a framework for performance analysis. Working paper no. 64. Overseas Development Institute, London

Dawson I, Were J (1997) Collecting germplasm from trees-some guidelines. Agrofor Today 9:6–9

Director General Land Rehabilitation and Social Forestry (DGLRSF) (2002) Decree No: 079/KPTS V/2002. Jakarta, Indonesia. www.dephut.go.id/informasi/rrl/sumber_benih.htm. Accessed 24 October 2007

Director General Land Rehabilitatiion and Social Forestry (DGLRSF) (2003) Jakarta, Indonesia. www.dephut.go.id/informasi/rrl/sumber_benih.htm. Accessed 24 October 2007

Harum F, Iriantono D, Roshetko JM (2006) Role of the forest tree seed sub-sector in procurement of high-quality germplasm for tree planting programs in Indonesia. Paper presented at the national tree seed forum, Manila, Philippines, 27 January 2006, 10 pp

Harwood C, Roshetko JM, Cadiz RT, Christie B, Crompton H, Danarto S et al (1999) Domestication strategies and process. In: Roshetko JM, Evans DO (eds) Domestication of agroforestry trees in Southeast Asia. Forest, farm, and community tree research reports, Special issue. Winrock International, Morrilton, Arkansas, USA, pp 217–225

Hughes CE, Stewart JL (1990) Enterolobium cyclocarpum: the ear pod tree for pasture, fodder and wood. NFT highlights. NFTA 90-05. Nitrogen Fixing Tree Association. Winrock International, Morrilton, Arkansas

Koffa SN, Garrity DP (2001) Grassroots empowerment and sustainable in the management of critical natural resources: The Agroforestry Tree Seed Association of Lantapan. In: Coxhead I, Buenavista G (eds) Seeking sustainability: challenges of agricultural development and environmental management in a Philippine watershed. Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños, Laguna, Philippines, pp 97–215

Koffa SN, Roshetko JM (1999). Farmer-managed germplasm production-diffusion pathways in Lantapan, Philippines. In: Roshetko JM, Evans DO (eds) Domestication of agroforestry trees in Southeast Asia. Forest, farm, and community tree research reports, Special issue. Winrock International, Morrilton, Arkansas, pp 142–150

MOF (Ministry of Forestry) (2001) Statistik Kehutanan 2001. www.dephut.go.id/content.php?id=159andlev=1. Accessed 24 October 2007

MOF (Ministry of Forestry) (2003) Tentang pembentukan tim koordinasi perbaikan lingkungan memalui rehabilitasi dan reboisasi nasional. SKB No.09/KEP/MENKO/KESRA/III/2003; KEP. 16/M.EKON/03/2003; KEP.08/MENKO/POLKAM/III/2003. Accessed March 2004

Mulawarman, Roshetko JM, Sasongko SM, Iriantono D (2003) Tree seed management: seed sources, seed collection and seed handling: a field manual for field workers and farmers. World Agroforestry Centre (ICRAF) and Winrock International, Bogor, Indonesia

Ochsner P, Lusianto U, Siswandi J (2004) Report on how to increase the distribution of quality seed from the seed dealers in the Ponorogo Wonogiri area. Indonesia Forest Seed Project; Regional Forest Tree Seed Centre, Java and Madura; and Directorate of Forest Tree Seed, Ministry of Forestry, Jakarta, Indonesia

Roshetko JM (2001) Strengthening germplasm security for ngos and smallholders in Indonesia. First annual report. ICRAF and Winrock International, Bogor, Indonesia

Roshetko JM (2002) Better quality tree germplasm for farmers and NGOs: 2001 annual report of the strengthening tree germplasm security for NGOs and smallholders in Indonesia sub-project. ICRAF and Winrock International, Bogor, Indonesia

Roshetko JM, Mulawarman, Suharisno S, Iriantono D, Harum F (2003) Direktori Penyedia Benih Pohon di Indonesia (Directory of Tree Seed Suppliers in Indonesia). Edisi Kedua, Second edn. World Agroforestry Centre (ICRAF) dan Winrock International, Bogor, Indonesia

Simons AJ, MacQueen DJ, Stewart JL (1994) Strategic concepts in the domestication of non-industrial trees. In: Leakey RRB, Newton AC (eds) Tropical trees: the potential of domestication and rebuilding of the forest resources. HMSO, London, pp 91–102